

8.1 EXCESS SLUDGE QUALITY AND QUANTITY

The quality and quantity of the excess sludge produced from an activated sludge process depends on the nature of the waste water to be treated, the process configuration and the operational conditions of the process. When primary sedimentation is applied (this often implies that anaerobic sludge stabilisation will be used as well), the produced excess sludge mass will be larger than in the case of raw sewage treatment. This can be demonstrated as follows: if it is assumed that a fraction R_p of the influent COD is removed in the primary settler, the primary sludge production can be estimated as R_p/f_{cv} kg VSS.kg⁻¹ COD. If the organic sludge fraction in primary sludge is assumed to be equal to the organic fraction of the secondary sludge (i.e. an f_v value between 0.6 and 0.8), the total suspended solids production in the primary settler is equal to:

$$mE_{t1} = R_p/(f_{cv} \cdot f_v) \quad (8.1)$$

If it is further assumed that the primary sludge is thickened in the primary settler to a concentration X_{d1} , the flow of primary sludge per unit mass of daily applied COD is:

$$mq_1 = mE_{t1}/X_{d1} = R_p/(f_{cv} \cdot f_v \cdot X_{d1}) \quad (8.2)$$

In the case of sewage treatment, typical values found in practice are $R_p = 0.33$, $f_v = 0.75$, and $X_{d1} = 40$ g TSS.l⁻¹. For these values the specific primary sludge mass and -volume are calculated as $mE_1 = 0.33/(1.5 \cdot 0.75) = 0.29$ kg TSS.kg⁻¹ COD and $mq_1 = 0.29/40 = 7.3$ litre.kg⁻¹ COD. For a per capita contribution of 100 g COD.d⁻¹, the estimated daily primary sludge production is 29 gram TSS in 0.73 litre.inh⁻¹. The mass of produced secondary sludge depends on the efficiency of primary settling, but also on the applied sludge age. With the aid of Eq. (3.51) and assuming a COD removal efficiency R_p in the primary settler, one has:

$$mE_{t2} = (1 - R_p) \cdot [(1 - f'_{ns} - f'_{np}) \cdot (1 + f \cdot b_h \cdot R_s) \cdot C_r/R_s + f'_{np}/f_{cv}] / f_v \quad (8.3)$$

Where:

mE_{t2} = excess sludge production per unit mass applied COD

f'_{ns} / f'_{np} = non-biodegradable dissolved and particulate COD fractions in the settled sewage

In general, it is more difficult to thicken secondary sludge. In Section 6.5 it was shown that in many cases the thickened sludge concentration will not be higher than 20 to 25 g TSS.l⁻¹. The secondary sludge flow can be expressed as:

Where:

$$mq_2 = mE_{t2}/X_{th} \quad (8.4)$$

mq_2 = secondary sludge flow per unit mass of daily applied COD

X_{th} = secondary sludge concentration after thickening

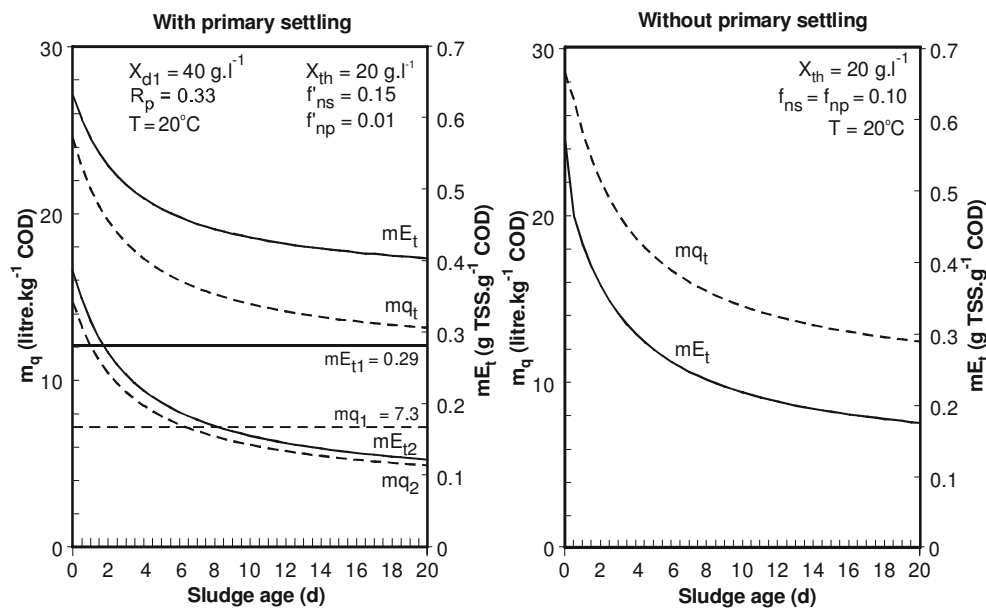


Figure 8.1 Excess sludge production as a function of sludge age for processes with (left) and without (right) primary settling

Fig. 8.1a shows the primary and secondary sludge production per unit mass of applied COD as a function of the sludge age in the activated sludge process. To construct the diagram the following values were assumed:

- COD removal efficiency in the primary settler $R_p = 0.33$;
- $f_{ns} = f_{np} = 0.10$ in the raw sewage;
- $f'_{ns} = f_{ns}/(1 - R_p) = 0.1/(1 - 0.33) = 0.15$ (the non-biodegradable dissolved COD concentration is not effected during the settling process) and $f'_{np} = 0.01$. In practice the fraction f'_{np} always has a low value (< 0.03).

Fig. 8.1b is similar to Fig. 8.1a, but calculated for a configuration without primary settling. When the two diagrams are compared, it can be noted that primary settling tends to increase the production of excess sludge: for the range of sludge ages usually applied in practice, the total sludge production is 20 to 30 percent higher. In contrast, the volume of the excess sludge in the case of primary settling tends to be smaller, because primary sludge is easier to thicken and therefore will have a higher concentration than secondary sludge. Sludge treatment (either aerobic or anaerobic) leads to a reduction of 30 to 50 percent in the excess sludge solids content. After stabilisation the sludge usually has much better settling properties, so that a higher concentration may be obtained by thickening. Fig. 8.2 shows the relationship between the sludge volume and the concentration of solids. In the same diagram the influence of the water content (humidity) on the physical characteristics of sludge is shown:

- Up to a solids concentration of 20 - 25%, the sludge behaves like a fluid;
- At higher concentrations up to 30 to 35%, it is more of a "cake". Above this concentration, it is considered to be a solid;
- Granule formation begins when the solids concentration increases to 60 - 65%;
- Finally, above 80 - 90% solids content, the sludge is transformed into a fine powder.

It can be observed in Fig. 8.2 that in order to transform stabilised excess sludge (with a solids content of 20 to 50 g TSS.l⁻¹) into a solid (for example with 30 percent solids), the final volume will be only 7 to 17 percent of its initial value, which means that about 90 percent of the originally present water must be removed.

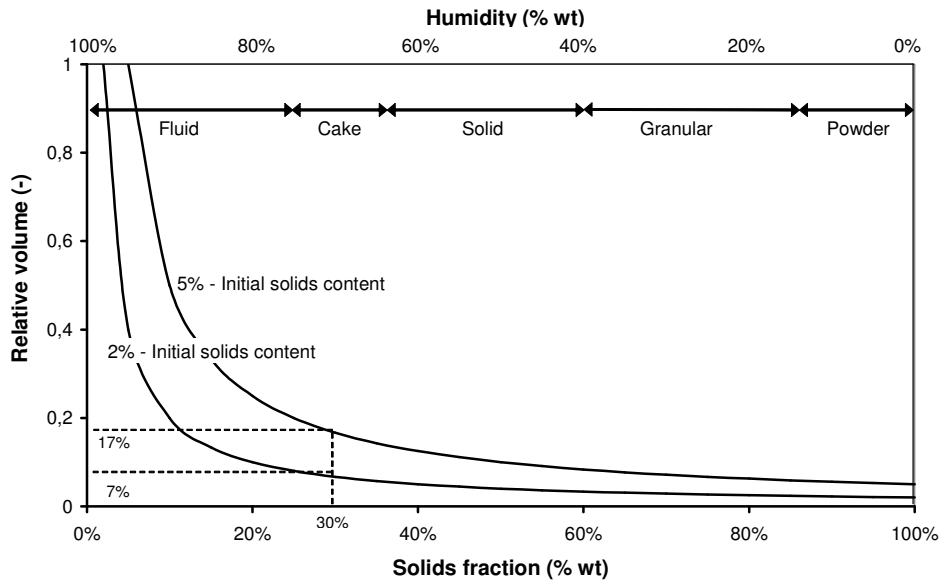


Figure 8.2 Relationship between solids fraction, humidity and relative sludge volume

When a drier sludge is required, this percentage rises to more than 95 percent. The composition of primary and secondary sludge is quite different. Whereas in the former, carbohydrates predominate and lipids have a significant concentration, in the latter the organic material is mostly of proteinic nature. Table 8.1 shows some experimental data of sludge composition, as determined by several authors.

Table 8.1 Composition of primary and secondary sludge (as % weight of the dry mass)

Component	Primary sludge			Secondary sludge	
	(1)	(2)	(3)	(4)	(5)
Volatile fraction	79.7	73.5	75.0	59 - 75	79.0
Lipids	18.6	21.0	10.3	5 - 12	5.8
Cellulose	18.2	19.9	32.2	7	9.7
Hemicellulose			2.5		
Proteins	17.2	28.7	19.0	32 - 41	53.7

Sources: (1) = O'Rourke (1968), (2) = Eastman and Ferguson (1981), (3) = Higgins et al (1982), (4) = US EPA (1979) and (5) = Pavlostatis (1985)